Gamma-Ray Spectroscopy

BOTH natural radioactive materials, such as potassium found in the soil, and manufactured radioactive materials, such as plutonium created in a reactor, emit energy in the form of gamma rays, x rays, electrons, or alpha particles. Gamma rays are often the most useful radioactive emission to measure, because they provide a unique fingerprint of a material's isotopic composition. Gamma-ray spectrometers provide the means to identify and quantify these isotopes.

Gamma-ray spectroscopy has proven to be a successful tool in many fields, such as in solar physics to learn more about the Sun, in astrophysics to determine the composition of galactic and extragalactic objects, and in nuclear physics to discover the basic structure of matter. In support of national security, the technology helps locate radioactive materials at shipping ports and border crossings. In support of nuclear safeguards, it helps identify and quantify the isotopes present at nuclear processing facilities. Additionally, in the field of medicine, gamma-ray spectroscopy is used with tracer drugs to identify biological processes and is a component of imaging systems that help locate tumors.

A team of Lawrence Livermore scientists and engineers, working with the U.S. Defense Threat Reduction Agency and the National Nuclear Security Administration's Office of Dismantlement and Transparency, has developed GeMini, a portable detection device that significantly advances the field of gamma-ray spectroscopy. The device design depends on the element germanium (hence the "Ge" in GeMini) for accurately detecting and identifying nuclear materials. Compared with other instruments, GeMini identifies nuclear materials with a higher level of certainty and at a considerable cost savings. Its design incorporates an innovative ultraminiature cooling system (hence the "Mini" in GeMini) with an infrared shielding mechanism developed at Livermore. Other features include rugged construction, low power consumption, automated operation, and small size. In fact, the instrument is so small it fits in the palm of one's hand.

The Laboratory has commercialized GeMini technology with NucSafe, a radiation detection company based in Oak Ridge, Tennessee. The GeMini development team, led by Livermore physicist Morgan Burks, received an R&D 100 Award for this innovative technology.

Resolution Is Crucial for National Security

GeMini's outstanding energy resolution is particularly important in national security applications, when it is critical to differentiate between legitimate and illicit sources of gamma rays. The portable instrument can easily be carried by first responders to determine radiation levels and identify isotopes at sites of nuclear incidents, and homeland security personnel can use it to help prevent terrorists from smuggling nuclear materials into the country.

GeMini features a detector made from an ultrapure germanium crystal. Gamma rays interact with the germanium and liberate electrons in proportion to the energy of the gamma ray. These electrons are collected by a strong electric field applied to the crystal and then read out with precision low-noise electronics. Many other substances can be used to detect gamma rays, but

Development team for GeMini (from left): Dennis Carr, Morgan Burks, Marianne Ammendolia, and Livermore retiree Del Eckels.

in the Palm of Your Hand

The GeMini gamma-ray spectrometer fits in the palm of your hand.

germanium offers the best resolution. However, germanium achieves its spectacular resolution only when cooled to cryogenic temperatures of about 100 kelvin (–173°C) or less. This cooling is typically achieved using liquid nitrogen.

Before the addition of electromechanical cooling technology, germanium-based spectrometers were confined to the laboratory, where liquid nitrogen is available. Livermore has played an important role in developing this technology. (See *S&TR*, May 2006, pp. 4–10 and September 2003, pp. 24–26.) The Laboratory's latest-generation GeMini eliminates the need for liquid nitrogen with its ultraminiature electromechanical cooling system and novel thermal isolation capability.

In recent years, germanium-based spectrometers that are electromechanically cooled and therefore free from the constraint of liquid nitrogen have appeared on the market. However, GeMini's extremely low power consumption, small size, and low cost enable it to excel in applications where rapid deployment and portability are important.

New Applications for Spectroscopy

GeMini's unique attributes take gamma-ray spectroscopy applications into new territories. The instrument was the first electromechanically cooled germanium spectrometer ever deployed in deep space. High resolution is important in space missions to accurately determine the surface composition of a planet or an asteroid. A version of GeMini was launched on the National Aeronautic and Space Administration's (NASA's) MESSENGER spacecraft in 2004 and is currently collecting the first-ever gamma-ray data from the planet Mercury. In addition, GeMini may be part of a NASA mission to the Trojan asteroids near Jupiter. No other gamma-ray detector provides the high resolution, low weight, and rugged durability required in space exploration.

The portability of GeMini makes it ideally suited for civilian first responders in the case of a natural disaster where a concern of radioactive contamination exists. In addition, U.S. military personnel could find the detector useful when responding to potential terrorist threats involving nuclear weapons or dirty bombs (devices made of conventional explosives and radioactive materials). A version of GeMini is being built for the international safeguards community to use in field inspections of nuclear processing facilities.

GeMini has opened up a wide range of new applications for high-resolution, gamma-ray spectroscopy. The detector will soon be available to emergency first responders, homeland security personnel, and International Atomic Energy Agency inspectors. Wherever a need exists to identify nuclear materials with high precision, whether on the planets of our solar system or closer to home, GeMini will offer that capability in a low-cost, handheld package.

—Arnie Heller

Key Words: gamma-ray spectrometer, GeMini, germanium, International Atomic Energy Agency, nuclear safeguards, radiation detector, R&D 100 Award.

For further information contact Morgan Burks (925) 423-2798 (burks5@llnl.gov).